Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

SAFER-LC project: Safer Level Crossings by integrating and optimizing road-rail infrastructure management and design

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Abstract

Level Crossings represent vulnerable points in the European land transport system, since collisions at level crossings account for a high number of fatalities and serious injuries among road users and lead to major disruptions of railway operations. This paper presents part of the ongoing work conducted in the SAFER-LC EU project, namely an overview of indicators for level crossing safety solutions, taking into account the road and rail users' perspective. The paper identifies key safety criteria concerning the requirements coming from various types of level crossing users. The analysis focuses on human errors, attentional processes and risk perception, while paying special attention to vulnerable users such as pedestrians. The results are discussed in the context of a Human Factors methodological framework which analyses how technological and non-technological safety measures can be better adapted from a user perspective to make level crossings more self-explanatory and 'forgiving'. The implications for the implementation and evaluation of 'user-friendly' safety measures at level-crossings are also discussed.

Keywords: level crossing; rail safety; road safety; human factors; accident prevention.

1. Introduction

Level Crossings (LCs) represent vulnerable points in the European land transport system. Collisions at LCs can have severe consequences in terms of lost human lives and cause significant economic losses due to damage to material as well as via resulting delays. According to the European Agency for Railways (ERA, 2014), in Europe there are on average five LCs per 10 kilometres of railway line, representing over 118,000 LCs across the European Union (EU), half of which are passive. ERA figures showed that in 2012 that there were 573 significant LC accidents in the EU resulting in 237 fatalities and 336 serious injuries. Over the past few years, one person has been killed and close to one seriously injured every day on EU LCs; and the average LC accident (recorded and classified as significant at EU level) costs as much as EUR 1.7 million (ERA, 2014).

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LCs are the interface between road and rail, thus the safety management of LCs is a shared responsibility for both road and rail stakeholders. Therefore, it is reasonable to conclude that a cross-modal approach is needed to provide efficient solutions against collisions at LC. In addition, level crossing safety is a topic that has to be addressed from a technological as well as a human centred perspective, since human factors have been identified as the primary contributors to accidents at level crossings in Europe (ERA, 2014; UIC, 2017). Inattentive crossing or careless risk taking are examples for human factor issues that should be considered.

1.1. SAFER-LC research project

Therefore, SAFER-LC (Safer level crossing by integrating and optimizing road-rail infrastructure management and design) aims to improve safety of LCs by minimising risk of LC accidents. This will be done by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management of LC safety and by developing alternatives for the future design of level-crossing infrastructure. SAFER-LC is a three-year research project funded by the European Commission within the H2020 programme. The project started in May 2017, with a consortium of 17 partners from 10 countries led by the International Union of Railways (UIC).

The solutions and tools that are being developed in SAFER-LC will enable road and rail decision makers to find more effective ways to: (1) detect potentially dangerous situations leading to collisions at level crossings, (2) prevent incidents by innovative user centred design, and (3) mitigate the consequences of disruptions due to accidents or other critical events. The project focuses both on technical solutions, such as smart detection services and advanced infrastructure-to-vehicle communication systems and on human processes to adapt infrastructure designs to road user needs and to enhance coordination and cooperation between different stakeholders from different land transportation modes. The challenge is also to demonstrate the acceptance of the proposed solutions by both rail and road users and to implement the solutions cost-efficiently.

1.2. Aim of this paper

This paper focuses on the part of the project concerning human processes, highlighting the human factor in the LCs safety approach. This paper presents an overview of indicators for level crossing safety solutions, taking into account the road and rail users' perspectives. This is being achieved by proposing an innovative Human Factors (HF) methodological framework. In the following sections we describe the draft structure of the framework, its development process, and its planned validation scheduled for the second part of the project. The implications for the implementation and evaluation of user-centred safety measures at LCs are also discussed.

2. SAFER-LC Human Factors methodological framework

The HF methodological framework under development is based on existing data sources and analytical tools. The framework will be used in the project to evaluate the efficiency of LC layouts and safety measures with respect to road users' needs, cognitive processes, and behaviour.

The HF methodological framework uses sets of indicators or 'criteria' for self-explanatory, forgiving and safe LC design against which the safety measures will be objectively evaluated by being assigned a score rating which is still under development. The sets of relevant criteria are being identified and selected based on rail human factors literature, published studies, or suitable approaches from related research projects. In other words, the framework is driven both theoretically and from applied studies and lessons learnt in practice.

2.1. Theoretical development

Human Factors and Ergonomics use systems-based methods to support the design of complex and safe systems. An increasing number of researchers are arguing for the 'systems approach' to be taken when analysing and redesigning rail LC systems (e.g. Read et al, 2013; Salmon and Lenné, 2015; Stefanova et al., 2015). The advantage of the systems approach is that it considers all the relevant components within a LC context. This is important as road users with different individual characteristics interact with the various technologies in different LC environments.

The cognitive work analysis (CWA) framework (Vicente, 1999) has emerged as a promising approach for supporting the design of such systems. The recently proposed Cognitive Work Analysis Design Toolkit (CWA-DT) (Read et al. 2016) provides guidance and tools to assist in applying the outputs of CWA to design processes to incorporate the values and principles of sociotechnical systems theory (see for review, Walker et al. 2008) in rail transport settings such as LCs. For example, the following indicators are included: the view of humans as assets, the view of technology being a tool to assist humans, the promotion of the quality of life for rail level crossing users, the respect for individual differences, and upholding responsibility to all stakeholders. From these principles, one can derive more specific criteria of LC design and safety measures such as the suitability for all kind of road users (including vulnerable road users, VRUs, such as pedestrians or cyclists, as well as different kinds of motorists), acceptability by involved parties, or the degree to which LC infrastructure is self-explanatory.

From classical accident research, collisions at LCs can be linked to errors of perception, knowledge or decision-making (Grippenkoven & Dietsch, 2016; Lobb et al., 2001; Ward & Wilde, 1995). Errors have been defined as acts where the subject intends to follow the rules, yet the actions deviate from this intention. Well-known definitions of errors as well as in-depth classifications of errors can be found in the work of Hollnagel (1993) or Reason (1990). For example, in the LC environment a road user may fail to see the warning lights because of fatigue, inattention, poor lighting, limited sight distance, etc. (Freeman et al., 2013). A recent Australian study into the origins of rule breaking at pedestrian train crossings has shown that 24.5% of respondents intentionally violated the rules (Freeman & Rakotonirainy, 2015). These findings suggest that unsafe behaviour at LCs is likely to be driven not only errors, but also by violations. Violations are unsafe actions associated with an intention to deviate from regulations, rules and procedures, although the person has no intent of injury (see Reason, 1990, for review).

Unsafe behaviour resulting from violations may have different motivational roots and is likely to be associated with different personal, socio-cultural, and environmental variables (Lobb, 2006). It is therefore important to differentiate between these motives because the potential countermeasures or designs should also depend on the nature of the motivational context. Summala (1997) emphasized that external motives influence the level of risk individuals are willing to take (e.g., time pressure, mood). For example, when in a bad mood, drunk or simply in a hurry, drivers are prepared to compromise. This implies that external motives influence peoples' willingness to take risks. This is also in line with the more general literature of psychology and social sciences where there is widespread agreement that behaviour is influenced by its perceived benefits and, even more, by its perceived costs (e.g. Kahneman & Tversky, 1979). This means, for example, that the subjective discomfort caused by time loss can outweigh the perceived benefits of safe waiting behaviour. Therefore, including motivational aspects in the human factor analysis is important especially since the criteria on motivation, habits and systematic violations as voluntary unsafe behaviours are theoretically related.

On this basis, the SAFER-LC Human Factors methodological framework partially builds on the sets of criteria described in Table 1.

Table 1. Theoretically driven indicators for level crossing safety solutions, taking into account the road and rail users' perspective

Criterion	Definition	Example and possible quantification
Impact on safe behaviours	Positive behavioural adaptation when approaching a LC	Speed reduction (-km/h)
Impact on unsafe behaviours (involuntary)	Positive or negative effect on the errors committed by road users or rail users	Number of errors
Impact on unsafe behaviours (voluntary)	Positive or negative effect on the risky behaviours and violations committed by road users at the LC	Type of violation (e.g. zig-zagging) and their frequency
Impact on the user's motivation	How the measure integrates the needs of different road user categories	Short waiting time at LCs, time pressure
Impact on user's habits	How the measure is able to break the unsafe routines of frequent LCs users	Assuming they know the trains timetable at a specific LC (level of confidence)

Impact on VRUs	How the measure is adjusted to the vulnerability of road users such as pedestrians and cyclists	Type of VRUs (e.g. people with hearing disability)
Self-explanatory level	Level of implicit understanding of the measure by the end-user (i.e. easy to perceive and understand)	Possibility of language barriers in understanding signage

2.2. Previous research and empirical approaches

The SAFER-LC Human Factors methodological framework also builds on indicators adapted from past research as transferrable lessons. For example, the EU project RESTRAIL (REduction of Suicide and Trespass on RAILway property) used 14 criteria to assess the most cost-effective measures to prevent rail suicide and trespassing (Ryan & Kallberg, 2013). This methodology was successful to achieve the project goals, but was also adapted and used in practice, for example, to assess measures aiming to improve the safety of level crossings in Finland (Silla, Seise, & Kallberg, 2015). One should note that many of these criteria do not concern HF, but some of them can be further adapted in the SAFER-LC methodological framework (see Table 2).

Table 2. Complementary features adapted from the RESTRAIL project and used in the SAFER-LC methodological framework to assess level crossing safety solutions

Feature	Definition
Effect mechanism	Specifies the type of effect mechanism (impact) expected with the intervention
Target of safety effects	Specifies the categories of users who are targeted by the measure
Feasibility to different LCs	Specifies the types of LCs that the measure applies to
Circumstances where the measure is most effective	Specifies the circumstances where the measure is most effective or when it becomes ineffective
Integration with road/railway environment, other safety measures	Describes how the measure is integrated with the road/rail environment, other preventative measures or interventions
Acceptance (LC users, railway staff, people living nearby etc.)	Provides an estimate of how well the measure is accepted by the public and relevant stakeholders

These features refer to categorical variables and are therefore more qualitative in nature. The effect mechanism can typically include subcategories referring to various preventive layers with completely different goals:

- Improve the conspicuousness of train (colouring of the head of the train, LC mirrors, lighting systems etc.)
- Improve the conspicuousness of LC (active warning signs etc.)
- Restrict the access to LC (barriers)
- Reduce the approach speeds of vehicles (rumble strips, speed bumps, road swivelling etc.)
- Increase the awareness of correct behaviour and dangerousness of LCs (information campaigns, education etc.)
- Improve the physical environment of LC (wait platforms, inclination, maintenance etc.)
- Improve the possibilities of vulnerable road users to cross LC safely (rubber pads between the rails, barriers for VRUs, gates etc.)

The target of safety effects of measures can refer to all road users, including the vulnerable ones (e.g. pedestrians and cyclists). Similarly, the feasibility to different LCs can include a detailed classification of LC types (passive LCs without any warning devices, active LCs with barriers, active LCs with light and sound warning, active LCs with other warning devices, active LCs with traffic lights, LCs with low vehicle traffic, LCs with high vehicle traffic, LCs with paved road, LCs with gravel road, LCs with availability of electricity, LCs with low usage / not used at all, other).

The circumstances where a specific measure is the most effective can include particular environmental conditions affecting perception, or behavioural adaptation: daylight, darkness, twilight, rain, snowfall, slipperiness or poor visibility due to weather (fog). Further, the integration with road/railway environment or other safety measures could raise no problems, only minor problems that can be solved, or major problems. Finally, one could quantify acceptance (from total acceptance to total resistance) referring to all important categories of users and involved stakeholders: LC users, railway staff, people living nearby etc.

2.3. Future validation

The first version of the SAFER-LC Human Factors methodological framework and its application guideline will be used during the project trials to evaluate innovative solutions from safety and human factors point of view to enhance the safety of LCs. Most of the solutions and measures developed in SAFER-LC will be tested and improved under a combination of environments in various test-sites (laboratory, driving simulator, living lab). The various test-sites available in SAFER-LC are a perfect fit for solutions and measures at different stages of maturity. Early stage developments can be tested in simulation environments or on controlled test tracks, while more sophisticated measures will be evaluated in field pilots.

The information collected in the demonstration phase through the HF methodological framework will allow the evaluation of the developed solutions and the drawing of recommendations on technical specifications as well as on human centred improvements and organizational processes. At the same time, based on the experiences gathered at the test-sites the human factors methodological framework will be improved.

3. Discussion and conclusions

This paper described an ongoing work conducted in the SAFER-LC project with regard to the Human Factors methodological framework. This framework proposes several indicators to classify and assess LC safety solutions, taking into account the road and rail users' perspectives and requirements.

SAFER-LC will define passive and active measures to improve safety at LCs. which will be assessed and classified using the HF methodological framework. This assessment process will test the user-centred design and will enable the adaptation of infrastructures to the road and rail user perspective, with a focus on self-explaining and forgiving LCs.

Beyond technical feasibility, SAFER-LC will focus on the acceptability of the developed solutions and measures and the likely reaction of people to the tested measures. Trials shall include testing the reactions of people having different user profiles (e.g. road users, train drivers, road and rail transport authorities) taking into account age, gender and cultural background. The research will employ the HF methodological framework which will develop and validate new scales for specific criteria exposed in this paper.

The application of the HF methodological framework in SAFER-LC will provide (1) support to road and railway stakeholders to implement LC safety measures aiming to reduce human errors and violations related to infrastructure design; (2) new approaches to raise awareness of HF related issues in collision prevention at LCs; (3) particular attention to vulnerable road users (pedestrians, cyclists, etc.); (4) better knowledge of the human requirements of LC users by unifying all the existing research and analytical tools available; and (5) an easy-to-use tool to evaluate the efficiency of different LC designs and safety measures with special focus on HF issues.

Therefore, the use of HF framework, which is currently under development, will help both road and rail stakeholders involved in LC safety work to better understand the road users' needs and related requirements. This way, the road users' needs and requirements can be taken into account in the implementation of future designs for level crossings. This will enable the optimisation of the design of LCs and the associated safety solutions and measures in Europe and beyond by: (a) boosting the innovation potential for the industry in this area, (b) enhancing the safety levels of LC users, and (c) contributing to the development of more self-explanatory LC infrastructure.

The framework will be used during the project lifetime to evaluate the efficiency of LC layouts and safety measures with respect to road users' needs, cognitive processes, and behaviour. As it is being designed not only as a theoretical tool but also as a practical one, it will allow the LC stakeholders to tailor unique solutions for different LC situations after the end of the project. Based on the evaluation carried out with the framework, one will be able to make informed suggestions on the design of the layout of LCs to make them "user friendly". For example, if LCs are located in areas of high workload and visual clutter for road users, alternative signage directed to other areas of their cognitive performance will be suggested in order to enhance the self-explanatory and forgiving nature of the LC infrastructure for the users.

The main added value of the SAFER-LC project in the context of LC safety is related to the integration of various aspects of LC systems (human, infrastructure, technologies, management), the HF framework and the development of an easy access for decision makers on European level to the SAFER-LC results. Eventually, the SAFER-LC project will propose a combination of recommended and innovative technical specifications, human centred measures and organisational and legal frameworks for implementation. These will be delivered through a toolbox accessible through a user-friendly interface which will integrate all the project results and solutions to help both rail and road managers to improve safety at level crossings.

Acknowledgements

SAFER-LC project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723205.

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